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1 Why Classify?

Classification and the Diversity of Life

Nature is filled with a stunning array of living things – animals, insects, plants, fungi, bacteria, and more. This is apparent not just to the biologists who study life, but also to anyone who has ever taken a walk in a park, spent a day at a zoo, watched a nature documentary, or wondered about the pets and pests that share a living space with us. To think about the diversity of life in these terms – as ‘animals,’ ‘insects,’ ‘plants,’ and so on, is to classify it. It seems to imply a division of the world into different *kinds* of things – an animal kind, insect kind, and plant kind.

As anyone who has studied biology knows, modern biological classification goes far beyond the everyday vernacular terms ‘animal,’ ‘insect,’ and ‘plant,’ employing a system based on the ideas of the Swedish botanist Carolus Linnaeus, who developed a framework for classifying living things (as well as minerals) that was hierarchical and comprehensive. According to this approach, all individual organisms are grouped into species that are then grouped together into higher level taxa – genera, orders, classes, and kingdoms. Linnaeus also proposed a naming system based on genus and species membership. He gave humans, for instance, the name *Homo sapiens*, where the first name denotes the genus and the second name identifies the species taxon within the genus. For Linnaeus, an individual human was a member of the species *sapiens*, which was itself a member of the genus *Homo*. *Homo sapiens* was then part of the hierarchy, by being a member of higher level taxa – the order Anthropomorpha, class Quadrupedia, and kingdom Animale.

The Linnaean system was adopted by Charles Darwin and given an evolutionary interpretation. For Darwin, the group-in-group hierarchy of the Linnaean system could represent the branch-on-branch structure of the

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evolutionary tree, which in turn could represent evolutionary diversification as new species form and diverge. Since Darwin this system has become fully embedded in our practices and institutions – our zoos, natural history museums, biodiversity studies, and collections. Nonetheless, the practice of biological classification is not yet settled. There are four main ongoing philosophical debates about classification. The first is *theoretical*: What should a biological classification represent? Linnaeus may have thought that classification should represent the ideas of God that governed creation, but Darwin and his followers thought biological classification should instead have an evolutionary basis, representing genealogy and degree of divergent change. On Darwin's approach, which came to be known as "evolutionary taxonomy" or "evolutionary systematics," organisms should be grouped together based on common ancestry, but the resulting taxa should be *ranked* on degree of divergence. The Linnaean class Aves, for instance, contains many species of birds, all with a common ancestor. But because this group is so large and has undergone such great modification, it was given an elevated taxonomic rank.

Another evolutionary approach was developed in the second half of the twentieth century by a group of systematists known as "cladists" or "phylogeneticists." They followed Darwin's example in basing classification on genealogy (phylogeny), but rejected the idea that ranking should be based on degree of divergence. According to this approach, a classification should represent only phylogeny, and more specifically, only the branching process in evolution as new species form. This makes a difference in classification. Cladists do not elevate *Aves* to a class, and instead treat birds as the clade (branch) Avialae in Theropoda, a taxon that also includes dinosaurs (Weishampel, Dodson, and Osmólska 2004).

But some systematists have rejected the idea that classification should represent evolutionary history at all. In part this is motivated by the fact that we lack precise knowledge of the phylogenetic origins of all species. We may know, for instance, that all birds share a common ancestry, but we don't know the precise branching order throughout Aves and so can reconstruct only the outline of the evolutionary tree here with any confidence. Consequently we cannot classify on evolutionary grounds with certainty. Moreover, if classification represents evolutionary history and our reconstruction of that history changes, then the classification must change as well. What we can have though, according to these systematists, is a

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system based on the detailed analysis of similarities and differences among taxa – a "phenetic" system. Organisms that are most similar overall get grouped together at all levels.

The second philosophical debate is about *operational procedures*: How should a classification be generated? The answer to this question is obviously dependent on the answer to the theoretical question about what a classification should represent. Linnaeus primarily used "fructification" traits – traits related to reproduction, thinking that was the best way to uncover the secrets of God's design. The Darwinians who followed, and believed that classification should represent evolutionary history, argued that classifications should be based only on "homologies" – shared traits due to common ancestry, and not on "analogies," similarities based on convergent adaptive change. But how shared traits can be established as homologies has generated some controversy. Evolutionary taxonomists have typically used assumptions about evolutionary processes in general, and the operation of natural selection in particular, to determine which shared traits are homologies and indicate a common ancestry. Cladists (phylogeneticists) have disagreed, arguing that this method is circular. Assumptions about evolutionary processes cannot be used to reconstruct the evolutionary past, because those process hypotheses can be confirmed *only* from the reconstruction of evolutionary history. Cladists have advocated an alternative method based on a parsimony principle they allege to be theory independent. According to this principle, the best hypothesis about the evolutionary past is the one that requires the fewest assumptions of evolutionary change. And in contrast to both the evolutionary taxonomists and the phylogeneticists, those who advocate a phenetic system, based only on similarities and differences, have typically endorsed the use of all similarities and differences, rather than just those traits deemed homologies. This makes sense because the phenetic classification was never intended to represent evolutionary history, only overall similarity.

The third philosophical debate is about the role of *tree thinking* in biological classification. The only diagram in the first edition of Darwin's *On the Origin of Species* was of a branching tree that represented the divergent speciation in evolution. As Darwin used the group-in-group structure of classification to represent the branch-on-branch structure of this tree, the tree metaphor has permeated thinking about evolution and biological classification. Recently there have been attempts to reconstruct the one grand

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tree of life. But there have also been recent challenges to tree thinking. First, we can construct different and conflicting trees, depending on what interests us: species taxa, organisms, character traits, or genes. The evolutionary history of genes, for instance, has tree-like structures, but gene trees often conflict with species trees. Second, while evolutionary trees typically represent only branching and diverging, there is now believed to be substantial reticulation – the rejoining of branches, through introgression, hybridization, or horizontal gene transfer, especially among plants, bacteria, and viruses. The strictly branching structure of the tree of life does not seem to accurately represent the complicated and messy evolutionary history. Some think we should therefore abandon this tree metaphor.

The fourth philosophical debate, about *ranking*, is a consequence of the idea that classification should be based on the evolutionary tree. *If* biological classification represents a branching evolutionary tree, then the Linnaean hierarchy and naming system appear to be radically inadequate. The current twenty levels or so of the hierarchy cannot possibly represent all the branches of the multibillion-year-old evolutionary tree. How then can we name and organize all the taxa? Indentation and numerical methods have been proposed, but the Linnaean system has become so entrenched in how we think about and represent biodiversity that it is hard to see how it could be abandoned. Is it possible to modify the Linnaean system to better represent evolutionary history and the full diversity of life?

These philosophical debates cannot just be brushed aside. Anyone who is engaged in the classification of living things relies, implicitly at least, on assumptions about what should be represented and how a classification should be constructed. This book aims to look at these issues, not from a partisan perspective (although I have also been a participant in these debates) but from that of a mostly impartial observer. This does not imply that we must avoid any conclusions at all about the various claims, but it does require that we look at them carefully and objectively. But before we look at these issues that have engaged professional systematists about *biological* classification, we need to understand classification in general. After all, modern biological classification is just one species of classification.

What is notable about biological classification is that it need not begin with or depend on the scientific approach based on the Linnaean system. Without consulting biologists we easily distinguish cats from dogs, bees from spiders, birds from fish, and plants from animals. And we seemingly

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do all this naturally and in the absence of any explicit theory of classification. But why do we classify? One initial answer is that we classify because we must. Classification is an unavoidable natural human tendency. And there is a tendency to classify many kinds of things, not just the living things of our biological classifications. To understand classification in general, we can approach it naturalistically, treating it as natural phenomena to be studied scientifically.

A naturalistic approach reveals that classification is universal. People in all known cultures classify living things, and in roughly similar ways. This is hardly surprising, given what we now know about the psychology of classification. Through observation and experiment, linguists and cognitive psychologists have come to understand what seems to be an innate and universal human tendency to classify in particular ways. In this chapter, we will look first at how people in different cultures think about and classify living things, and then at what developmental linguistics can tell us about the psychological basis for classification. But not all classifications are equal. Some seem to reflect real divisions in the world, while some seem arbitrary or merely pragmatic. On one standard philosophical way of thinking, we can understand this distinction in terms of the differences between *natural kinds* and the merely *conventional* or *artificial kinds*. We will briefly look at this natural kinds framework at the end of the chapter.

A comprehensive understanding of biological classification also requires that we know something about its history. Just as we understand human nature partly though what we know about the evolution of *Homo sapiens* – its origins in a primate lineage and its modification by natural selection and other processes, we can understand biological classification partly through knowledge of its origins and development. In Chapter 2 we look at what many see as the beginning of biological classification in Aristotle's use of the classificatory terms 'eidos' (translated into Latin as 'species') and 'genos' (translated as 'genus'). We will also look at how the Aristotelian framework was adopted and transformed in the 1,500 years after his death. In Chapter 3 we first look at the beginnings of the modern empirical approach to classification in the work of the medical herbalists and early naturalists. Then we delve into how that approach was developed by Linnaeus and given an evolutionary gloss by Darwin. Chapter 4 shows how Darwin's interpretation of the Linnaean framework was further developed in the twentieth

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century by the evolutionary taxonomists, and then how it was challenged by pheneticists and cladists.

Tree thinking is implicit in the evolutionary approaches that take classification to represent the structure of the evolutionary tree. In Chapter 5 we look at the various ways trees have been used, and the potential problems with trees posed by ranking, hybridization, and horizontal gene transfer. Chapter 6 is on what seems to be the most theoretically significant level in classification – the species level, and the many ways of thinking about species. Chapter 7 is on the metaphysical foundation of classification. How should we think about the basic, fundamental nature of biological taxa? Chapter 8 looks at the relation between evolutionary theory and classification, and contrasts empiricist and theoretical approaches. In Chapter 9 we conclude with what seems to be a fundamental and deep-seated tension between the psychology of classification and the modern scientific and theoretical foundations of biological classification. Our psychology leads us to think about biological classification in one way and our theories about the world lead us in conflicting ways. As this tension lies behind many of the philosophical debates in biological classification, we can perhaps better understand these debates by understanding this tension.

The Anthropology of Classification

One reason to think that classification is natural is that all people seem to do it, not just professional biologists. This is apparent in the studies of *folkbiology* – how the "folk" or nonscientists think about living things, *ethnobiology* and *ethnotaxonomy* – how the members of different cultures think about life and its classification. What these studies seem to reveal are broad cross-cultural similarities in the classification of life. To avoid the bias of modern theoretical biology, ethnobiological studies have typically focused on those cultures least influenced by modern scientific ways of thinking, from the Native American cultures of the Americas, to a variety of relatively isolated cultures of Southeast Asia and Africa. Typically an ethnobiologist will question an educated local "informant" about the names and features of the living things in the local environment, hoping to discover the vernacular terms the informant applies to these, and the implicit classificatory structure. Jared Diamond and K. David Bishop used this method with the Ketengban people of New

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Guinea. Over a period of three weeks in 1993, they spent eight to eleven hours a day walking through the forest with their informants, mostly observing birds.

> Our principal method for eliciting bird names consisted in asking Ketengban guides for the name of a bird that we and they both saw, or else heard, while walking together. In order to distinguish which individual bird we meant if there were several in sight or calling, we either pointed to the bird or imitated the call that we were hearing. In order to check that the Ketengban name given in reply actually was meant to refer to the bird about which we were inquiring, we asked our Ketengban guides to describe the bird to us in detail – in particular, its bill, tail, size, color diet, and forest stratum in which it is normally foraged. In that way we could ascertain whether they and we were really talking about the same bird, and whether they were really familiar with the species. (Diamond and Bishop 1999, 23)

Their results:

> We recorded 169 Ketengban bird names, identified most of them definitely, and identified most others tentatively. We also recorded 127 Ketengban names for trees, 51 names for mammals, 34 names for frogs, 16 names for lizards, 9 names for snakes, 6 names for spiders, 4 names for butterflies, and a few names for other insects and fungi, but we will not discuss these other Ketengban names because we do not know the scientific identities of most of them. (Diamond and Bishop 1999, 23)

The last sentence of this quote hints at an obvious complication. Ethnobiologists typically approach and understand the thinking of the local informants within the framework of their own scientifically informed views. If they know much about Linnaean classification, as Diamond and Bishop do, then this likely becomes the basis of the comparison. But Diamond and Bishop also formulated their questioning to uncover ecological or behavioral classifications that would not obviously fit into the modern, evolutionary Linnaean framework:

> Gradually, as we became familiar with many Ketengban names, we structured the questioning by asking our informants to name and describe to us all night birds, or all grassland birds, or all ground-dwelling birds, or all birds similar to some species (e.g., a parrot or pigeon species) whose vernacular name we had already identified. (Diamond and Bishop 1999, 31)

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Notice that *Grassland birds* is a hybrid category, based partly on ecology, and groups together birds that are not necessarily closely related in evolutionary terms. Similarly, *night birds* and *ground-dwelling birds* are partly behavioral and ecological groupings. So none of these taxa would fit into the modern evolutionary Linnaean framework based on common ancestry.

The most obvious thing to notice about the findings of Diamond and Bishop is that the Ketengban informants have specific names for, and know a great deal more about the living things in their environment than do the average members of modern, scientific societies. This is unsurprising since their daily life depends much more on knowledge of the animals and plants in their environment than does life in urban and suburban cultures. But another notable conclusion, according to Diamond and Bishop, is that the vernacular Ketengban bird names *seem* to refer to the bird species recognized by scientists, with just a few exceptions where a group of related species might be given a single name, or a sexually dimorphic species might have different names for the female and male (Diamond and Bishop 1999, 35–38).

Diamond and Bishop also looked at the hierarchical structure of the Ketengban classification, and compared it to the Linnaean system:

> Scientific nomenclature for a local biota is hierarchical, with four major levels below the class level (birds being the class Aves). Those four levels are the order, family, genus, and species. In contrast, Ketengban names belong to only two levels: a low-level terminal category corresponding closely to species, and a high-level collective category corresponding approximately to classes or orders. The six collective Ketengban names that we obtained correspond respectively to birds, bats, mammals other than bats, snakes, lizards, and frogs. We found no evidence that Ketengbans name any category intermediate between the low-level terminal category and their high-level collective category. Even though Ketengbans readily understood our questions about naming all species in distinctive bird families, such as naming all parrot species or all hawk species, they offered no name for those intermediate categories (which scientists recognize as families or orders), despite their ability to grasp the bounds of the intermediate category. (Diamond and Bishop 1999, 32)

With the Ketengban there is a group-in-group structure, as in the Linnaean system. The lower level categories are grouped within increasingly higher

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level categories. And while the Ketengbans have names for only two levels of classification, they seem to recognize intermediate levels between the higher collective level and the lower terminal level.

Studies of the folk classifications of other cultures have arrived at roughly similar conclusions. First, these studies tend to find a relatively large number of names and categories of plants and animals. Brent Berlin's study of the Tzeltal Mayan's classification, for instance, found hundreds of names and categories of plants (Berlin 1999). And Scott Atran found hundreds of recognized categories of snakes, birds, and palms among the Itzaj Mayans (Atran 1999). Second, these studies tend to find a hierarchical structure, usually more complex than what Diamond and Bishop found in the Ketengbans. According to Berlin, there are up to six levels or ranks in the hierarchies he has studied. The highest is *kingdom*, followed by *life form*, *intermediate*, *generic*, *specific*, and *varietal* (Berlin 1992, 22). Not all of these hierarchical levels would necessarily be found in all cultures though. Nor will all the levels necessarily have a name (Berlin 1992, 31–33). Ralph Bulmer, in his studies of Kalam ethnotaxonomy, identified five levels of hierarchy, from the highest, *primary taxa*, which are not subsumable into any larger taxon, to the *terminal taxa*, which have no named subdivisions (Berlin 1992, 65). Third, there also seems to be a basic privileged level in the hierarchy. According to Berlin this is the *generic* level. Most of the taxa are found here. These taxa are easily recognizable and have simple names (such as 'dog' and 'cat' in the vernacular English; Berlin 1992, 64). Atran dubbed the groupings at this level 'generic species' (Atran 1999, 124).

What generalizations can we draw from these studies in the folkbiology of various cultures? First, all folk classifications seem to be hierarchical, with a group-in-group structure. Although Diamond and Bishop found only two explicitly named levels in their investigation of Ketengban folk classification, more levels were implicitly recognized. Berlin, Bulmer, and Atran have all found more, albeit not always named, levels. Atran argued that there is a default hierarchy comprising five levels. According to Atran, the highest level is *kingdom* (Atran 1999, 122). Folk kingdoms, if not explicitly named, may be indicated by the use of a particular suffix or term. The Itzaj used a particular term only for plants, for instance. They also used a term translated as 'forest-thing' at the kingdom level that includes many vertebrates, invertebrates, birds, and fish (Atran 1999, 123). The next highest

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default level is *life form*, a level that is often based on functional, developmental, or ecological factors:

> The majority of taxa of lesser rank fall under one or another life form. Most life-form taxa are named by lexically unanalyzable names (primary lexemes), and they have further subdivisions such as tree or bird. Biologically, members of a single life form are diverse … Life-form taxa may represent general adaptations to broad sets of ecological conditions, such as the competition of single-stem plants for sunlight and tetrapod adaptation to life in the air. (Atran 1999, 122)

Among the Itzaj Maya, life forms in the plant kingdom include *trees*, *shrubs*, *vines*, and *grasses*. Animal life forms include categories roughly corresponding to mammals (excluding bats), birds (with bats), and herpetofauna (amphibians and reptiles) (Atran 1999, 123, fn. 5).

The third highest level is the *generic species*, usually identified as species-like groupings. This level seems to have a special status, and for a variety of reasons, linguistic, inferential, psychological, and developmental:

> The rank of generic species is the level at which morphological, behavioral and ecological relationships between organisms maximally covary. The majority of Itzaj folkbiological taxa belong to this level. It is this level that Itzaj privilege when they see and talk about biological continuities. Generic species represent cuts in nature that Itzaj children first name and form an image of … and that Itzaj adults most frequently use in speech, most easily recall in memory, and most readily communicate to others … It is the rank at which Itzaj, like other folk around the world, are most likely to attribute biological properties, including characteristic patterns of inheritance, growth, physiological function, as well as more "hidden" properties such as hitherto unknown organic processes, organs and diseases. (Atran 1999, 127)

The level of *generic species* seems to be the primary focus of how the Itzaj and other folk talk and think about living things. It is generic species that are most easy to identify, name, remember, and think about. And it is at this level that there is the strongest tendency to generalize: from the fact that some individuals of a generic species have some trait, other individuals must also have that trait. Generic species also typically have simple names, such as we see with the English vernacular terms 'dog,' 'cat,' 'oak' and 'robin.'

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